The Behavioral Equilibrium Exchange Rate of the Czech Koruna*

Martin Melecký# and Luboš Komárek*

Abstract

The behavioural equilibrium exchange rate (BEER) model of the Czech koruna is derived in this paper and estimated by three methods suitable for non-stationary time series. The considered potential determinants of the real equilibrium exchange rate are the productivity differential, the interest rate differential, the terms of trade, net foreign direct investment, net foreign assets, government consumption and the degree of openness. We find that the Czech koruna was on average undervalued over the period 1994 to 2004 by about 7 percent with respect to the estimated BEER. The significant determinants of the equilibrium exchange rate of the Czech koruna appear to be the productivity differential, the real interest rate differential, the terms of trade and the net foreign direct investment.

Keywords: Equilibrium Exchange Rate Modelling, Time-Series Analysis, Exchange Rate Misalignments, Czech Republic, ERMII

JEL Classification: C52, C53, E58, E61, F31

Corresponding Author:

Martin Melecky, School of Economics, John Goodsell Building, University of New South Wales, Sydney, NSW 2052, Australia

E-mail: **m.melecky@unsw.edu.au**

---

* We are grateful to Kirsten Lommatzsch (DIW Berlin), Bernd Schnatz (European Central Bank), Jan Frait, Jan Babetski and Roman Horvath (Czech National Bank) for helpful comments on the earlier draft of this paper.

Martin Melecký – School of Economics, University of New South Wales

* Luboš Komárek – Czech National Bank and Prague School of Economics

1 Introduction

Both policy makers and market participants have a strong interest in appropriate estimates of equilibrium exchange rates and their prospective movements. They have also a keen interest in understanding determinants of the equilibrium exchange rate and implied misalignments of the actual exchange rate. Overvalued or undervalued exchange rates induce suboptimal allocation of resources between importers and exporters. Additionally, an overvalued currency may lead to an unsustainable current account deficit, increasing external debt and the risk of possible speculative attacks (see e.g. Kaminski, Lizondo and Reinhart, 1997) with detrimental consequences for the economy. There is also a general belief that an overvalued currency leads to lower economic growth, but that an undervalued currency has an equivocal effect on growth (e.g. Razin and Collins, 1997).

The prospects of an undervalued or overvalued currency are one of the crucial policy problems faced by the new EU Member States that are supposed to adopt the euro in near future. The prospective euro area member is required to first enter the exchange rate mechanism, ERM II, which is a part of the Maastricht criteria on exchange rate stability, and subsequently announce their euro-locking rates. ECB (2003) recommends in its position documents related to ERM II participation that *"... the central rate should reflect the best possible assessment of the equilibrium exchange rate at the time of entry into the mechanism. This assessment should be based on a broad range of economic indicators and developments while also taking account for the market rate."* In broad terms, the "equilibrium" exchange rate refers to the rate, which is consistent with medium-term macroeconomic fundamentals. The medium term, usually defined as 2 to 6 years is often chosen as a benchmark in order to assess the level towards which the actual exchange rate is meant to gravitate.

The overall objective of this paper is to assess the behavioural equilibrium exchange rate of the Czech koruna by means of different estimation methods. The paper is structured as follows. Section two provides a brief overview of alternative concepts of equilibrium exchange rates, and derives the behavioural model of the equilibrium exchange rate for a transition country, which is later used to estimate the behavioural equilibrium exchange rate (BEER) of the Czech koruna. Section three discusses potential fundamental determinants of the real exchange rate of the Czech Republic, which may play a significant role prior to joining the euro area. Section four includes description of the constructed variables and their unit-root tests. Section five outlines employed estimation methods. In section six we carry out the estimations of the BEER model for the Czech koruna. Section seven discusses the resulting BEER and permanent equilibrium exchange rate (PEER) misalignments. Section eight concludes.

2 Concepts of EER and the BEER Model

2.1 Concepts of Equilibrium Exchange Rates

The analysis of the real equilibrium exchange rate could be divided into two main categories, for which various terms and names are used – fundamental (normative) and behavioural (positive) analyses.[1] A common starting point for inference on the

[1] For further discussion see e.g. Frait and Komárek (1999, 2001).

equilibrium exchange rate is to use the purchasing power parity approach. However, there is a strong consensus in the literature that PPP is not an appropriate measure for developing and transition economies. Countries in a catching-up process may experience a trend appreciation of the real exchange rate, the simple version of PPP does not account for.[2]

A medium-term concept of the equilibrium exchange rate (EER) useful for policy purposes is the fundamental equilibrium exchange rate (FEER) developed by Williamson (1994), which defines the EER as the real exchange rate that corresponds to simultaneous internal and external balances. The cornerstone of this approach is current account sustainability, i.e. the level of current account deficits/surpluses that match long-term capital inflows/outflows. However, the FEER approach needs a normative judgement regarding the size of long-term capital flows. Also, FEER estimates are usually derived from large scale macroeconometric models or partial trade blocks of a given economy. To circumvent normativity and the use of large macro models, the macroeconomic balance (MB) approach, which has been sharpened and widely used by the IMF[3], estimates directly the sustainable level of current account deficits (surpluses) based on saving-and-investment balance. The capital enhanced equilibrium exchange rate (CHEER) relates the nominal exchange rate, price level and interest rates in

---

[2] A well-known phenomenon explaining trend appreciation is the Balassa-Samuelson effect, which is based on market-based non-tradable price inflation driven by fast productivity gains. However, there are two other factors that can contribute to the trend appreciation of the real exchange rate: (i) the trend appreciation of the tradable price-based real exchange rate for example due to the improvements in terms of trade (ii) administered/regulated prices changes. For more detail, see Égert and Lommatzsch (2003) and Égert (2003).

[3] See Isard and Faruqee (1998) for an overview.

domestic and foreign country. According to MacDonald (2000), the CHEER is a medium-run concept in the sense that it does not impose stock-flow consistency. Similar in spirit to these approaches is the NATREX (Natural Rate of Exchange) model advocated by Stein (1994) and Stein and Allen (1995), which is also based on the idea of concurrent internal and external balances. As opposed to FEER, it focuses on both the medium term and the long term. The long term is then a period during which the capital stock and the foreign debt are assumed to converge to their steady-state values and the associate real exchange rate.

The behavioural equilibrium exchange rate (BEER) put forth by MacDonald (1997) and Clark and MacDonald (1998) draws on the real interest parity through which the real exchange rate can be connected to the fundamentals. The permanent equilibrium exchange rate (PEER) is a variant of BEER which aims to decompose the estimated BEER into a permanent and transitory component (see Gonzalo and Granger, 1995) with the permanent component being interpreted as the equilibrium exchange rate (see Clark and MacDonald, 2000). The latter two approaches constitute a focal point in this paper and we use them to obtain estimates of the real equilibrium exchange rate of the Czech koruna.

2.2 Outline of the BEER Model of the Czech Koruna

We start building the BEER model for the Czech koruna using the equation for the actual real exchange rate based on real uncovered interest parity (UIP):

$$q_t = E_t\left(q_{t+k}\right) - \left(r_t - r_t^*\right) + \omega_t \tag{1}$$

where q_t is the actual real exchange rate (RER), r_t and r_t^* are the domestic and foreign real interest rates with a maturity $t+k$, $E_t\left(q_{t+k}\right)$ is the conditional expectation of the $t+k$ period real exchange rate and ω_t is the time-varying risk premium. Further, $r_t = i_t - E_t(\pi_{t+k})$, is the *ex ante* real interest rate, where i_t is the nominal interest rate with a maturity $t+k$ and $E_t\left(\pi_{t+k}\right)$ is the conditional expectation of inflation, π_t, in period $t+k$. An increase in the risk premium ω_t is deemed to induce a depreciation of the RER which, given the model structure, generates an expected appreciation. The risk premium can be written out in full as:

$$\omega_t = \mu + \lambda_t + e_t \tag{2}$$

where μ is a constant, λ_t is some proxy for the unobserved risk premium and e_t is a white noise process. Following Clark and McDonald (1998) the proxy is assumed to be a positive function of the relative fiscal stance fs_t / fs_t^*:

$$\lambda_t = f^+\left(fs_t / fs_t^*\right) \tag{3}$$

hereafter the function $f(\cdot)$ is restricted to be linear. For instance, an increase in the relative supply of the outstanding domestic debt increases the risk premium on the domestic currency and induces a depreciation of the current real exchange rate.

Now, consider again equation (1). The conditional expectation is also restricted to be a linear function of the information set we will condition upon. It is convenient at this point to elaborate on the conditional expectation of the $t+k$ period RER given that we deal with some specifics related to an economy in transition. For this reason, let us decompose the expectation into two parts:

$$E\left(q_{t+k} \mid I_t\right) = E\left(q_{t+k} \mid I_t^*\right) + E\left(q_{t+k} \mid I_t^T\right) \tag{4}$$

where I_t^* involves the traditional determinants of RER of developed economies (see e.g. McDonald, 1997), and I_t^T is a set of determinants that are effective only during transition periods and their effect on the RER ceases to be significant as the countries accomplish their transitions (convergence to developed economies). Applying the assumption of linearity and using equations (2)-(4), (1) can be expressed as:

$$q_t = \mu + \theta_1 X_{1,t} + \theta_2 X_{2,t} + \theta_3 \left(r_t - r_t^*\right) + \theta_4 \left(fs_t - fs_t^*\right) + e_t \tag{5}$$

where $X_{1,t}$ is a subset of I_t^* and similarly $X_{2,t}$ is a subset of I_t^T, θ_1 is expected to be non-zero, $\theta_2 \rightarrow 0$ as t approaches the end of the transition period, θ_3 is expected to be equal to negative one if the real UIP holds, and θ_4 is expected to be positive.

3 Fundamental Determinants of the EER

Appendix 1 provides an overview of the empirical findings concerning the significant determinants of real exchange rates of the new EU Member States. Labour productivity or a proxy of it appears to enter the real exchange rate equation almost every time. There is strong evidence that an increase in productivity leads to an appreciation of the real exchange rate. However, the empirical findings on the signs of the other variables are mixed. Approximately one third of the papers finds that government expenditure, the degree of openness, net foreign assets, the foreign real interest rate or the real interest differential, and the terms of trade have a significant impact on the real exchange of the new EU Member States. In addition, some other variables such as foreign debt, private expenditure, investment and regulated prices seem to have a significant influence on the real exchange rate as well. The mixed results with regard to some variables are attributable to the different time horizons considered and the methodologies applied in particular studies.

Hence, the set of possible exchange rate determinants associated with the BEER approach is quite broad. We try to choose those which from the theoretical and empirical points of view might be the most relevant for the Czech Republic[4] and comply with our constraint on data availability. We thus choose to consider the productivity differential, the terms of trade, foreign direct investment, the degree of openness, net foreign assets, government consumption and the real interest rate differential as the potential determinants of the EER for the Czech Republic. We discuss expected influences of the determinants on the EER with regard to the time horizons (short-, medium-, or long-run effects), sector composition (exchange rate pressures due to different development in tradable compared to non-tradable sectors; in the domestic and foreign economy) and origin (domestic versus external) of the factors. The negative (positive) sign means that an increase in an explanatory variable is expected to induce an appreciation (depreciation) of the real exchange rate.

Productivity Differential *(-)*

A higher average productivity in the domestic relative to the foreign economy is typically expected to result in an appreciation of the domestic currency mainly due to higher domestic inflation as a result of faster productivity growth. This channel is traditionally associated with the Balassa-Samuelson effect. Assuming perfect labor

[4] These determinants are similar also for other new Member States of the EU.

mobility the latter effect tells us that if the productivity growth in the domestic tradable sector (manufacturing) is relatively higher than in the non-tradable sector (services) the wages in the tradable sector tent to increase. The perfect labor mobility equalizes the wages in both sectors and increases prices of the non-tradable goods hence increasing the overall price level in the domestic economy with respect to the foreign economy. The appreciation can however be materialized through the nominal exchange rate as well, as the increase productivity implies higher economic growth and higher demand for the domestic currency relative to the foreign currency.

Terms of Trade *(-)*

A positive shock to the terms of trade, e.g. an increase in prices of exported goods, is assumed to generate two effects. A *substitution effect* when the domestic production sector shifts the production towards tradable (exportable) goods resulting in higher wages in the tradable sector relative to the non-tradable sector. The wages equalize subsequently due to sufficient labor mobility inducing an increase in the overall domestic price level. The improvement in the current account and the higher domestic price level make the domestic currency appreciate. The *income effect*, on the other hand, comes about as the improvement in the trade balance raises income of the domestic economy and higher demand for the non-tradable goods emerges. To restore the internal equilibrium the real exchange rate is required to depreciate. The relative magnitudes of the substitution and income effects hinge on relative price elasticity of the demands for imports and exports.

Net Foreign Assets *(-)*

The balance-of-payment logic postulates that the current account deficits cumulate up to net foreign liabilities with associated dividends and rental payments. The interest has to be paid for by an improvement in the trade balance. This requires the currency to depreciate, thus increasing the international price competitiveness of the country's exports. On the other hand, the portfolio balance reasoning may require an opposite adjustment of the real exchange rate. The countries debt as a result of current account deficits has to be financed by internationally diversifying investors. To adjust they portfolio in the desired way they require a higher yield. With given interest rates the higher yield is achieved through an appreciation of the debtor country's currency.

Degree of Openness *(ambiguous)*

A relatively higher degree of openness predisposes a given country to more efficient transfers of knowledge and technology either in a direct or indirect form. It also enables the country to benefit from its comparative advantages to a higher degree. One can also argue that the country risk is positively related to the degree of openness since the country would suffer a significant loss by loosing its international connections. This variable can be viewed as corresponding to the transition bit of the real exchange rate dynamics since one would expect that a developed country experience only limited variation in its degree of openness.

Foreign Direct Investment *(-)*

The FDI inflow is expected to increase average productivity and eventually result in a domestic currency's appreciation. The effect of the FDI through the financial account works along the same lines. Namely, higher supply of foreign currency as a consequence of the FDI inflow induces a nominal appreciation of the domestic currency. In the long run, however, the current account deficit resulting from the factor payments on the productive FDI makes the currency depreciate as the debt grows. This variable has a substantial effect on the development of the real exchange rate in emerging market economies where the FDI flows are indeed substantial.

Real Interest Rate Differential *(ambiguous)*

An inclusion of the real interest rate differential is well justified by the BEER approach that derives the real exchange rate model from the underlying UIP the real interest rate differential is a part of. According to UIP, the currency with a positive interest rate differential is expected to depreciate so as to equate the yields in domestic and foreign currencies. The latter is required to eliminate any possible arbitrage opportunity. On the other hand, an increasing interest rate differential induces portfolio reallocation and higher demand for the currency with a relatively higher interest rate. This two opposite forces may result in an ambiguous impact of the interest rate differential on the exchange rate, even though, the theory underlying BEER is unequivocal in this respect.

Government Consumption *(+)*

In the long run, the growing budget deficit could have a destabilizing effect on the economy and lead to a depreciation of the real exchange rate, assuming the Ricardian equivalence holds. In the short run however, an increase in public consumption increases demand for non-tradable goods due to a higher share of non-tradable goods in public consumption relative to private consumption. Higher demand for non-tradable goods induces higher prices of non-tradable goods, i.e. a higher overall domestic price level, and consequently an appreciation of the real exchange rate. The overall effect of this variable might be thus ambiguous.

4 Data Description and Unit Root Tests

We use quarterly data covering the period from the first quarter of 1994 to the first quarter of 2004 (41 observations). The relevant series are seasonally adjusted by using the X12 procedure and Tramo/Seats method. The dependent variable is the CPI based real exchange rate and the description of explanatory variables follow. Plots of all the series involved in the estimations are available in appendix 2.

The real exchange rate (rer) – the log of the nominal exchange rate index against DEM (EUR) deflated by the consumer price index (CPI) in the Czech Republic and in Germany. A decrease of this index denotes a real appreciation of the real exchange rate. Data source: IMF IFS database.

Productivity differential (prod) - the relative productivity differential in the Czech Republic and Germany calculated as the ratio of real GDP over employment in both countries. Data source: IMF IFS and Eurostat, New Cronos databases (seasonal adjustment by authors).

Foreign direct investment (fdi) – the four quarter average of the ratio of net foreign direct investment over nominal GDP, both denominated in CZK. Data source: IMF IFS database (seasonal adjustment by authors).

Terms of trade (tot) - the ratio of export and import price indices. Data source: Eurostat, New Cronos database (seasonal adjustment by authors).

Openness (open) - the ratio of the sum of exports and imports relative to nominal GDP, all denominated in CZK. Data source: Eurostat, New Cronos database (seasonal adjustment by authors).

Net foreign assets (nfa) - The ratio of net foreign assets relative to nominal GDP, both denominated in CZK. Data source: IMF IFS database (seasonal adjustment by authors).

Government consumption (gs) - total government consumption over nominal GDP was used as an approximation of the fiscal stance of the Czech Republic. Data source: IMF IFS and Eurostat, New Cronos databases (seasonal adjustment by authors).

Real interest rate differential (rird) - The differential between Czech and German lending rates deflated by Czech and German CPI inflation, respectively. Data source: IMF IFS database.

We test for the order of integration of the series by employing the ADF-GLS test proposed by Elliott, Rothenberg, and Stock (1996). This test improves on the low power of the conventional ADF test in finite samples by estimating the coefficients on the deterministic variables in the test specification prior to the estimation of the coefficient of interest. The results are reported in table 1:

******* Table 1 Here *******

The variables *rer*, *prod*, *nfa* and *open* appear to be integrated to order I(1) and their underlying processes are expected to include both stochastic and deterministic trends. The *gs* variable is non-stationary, integrated to order I(1) as well with no deterministic trend. Variables *rird* and *tot* on the other hand appear to be stationary, i.e. integrated to order I(0). As the LHS variable and most of the RHS variables appear to be non-stationary we apply suitable estimation methods for non-stationary time series that we describe in the next section.

5 Applied Estimation Methods

The co-integration analysis is carried out using three methods so as to ensure some robustness of the acquired estimates. These methods are namely dynamic ordinary least squares (DOLS) introduced by Saikonen (1991) and Stock and Watson (1993), the auto-regressive distributed lag (ARDL) approach due to Pesaran and Shin (1995, 1999), and the full-information maximum likelihood (FIML) method due to Johansen (1995). We briefly describe the setup of the estimations below.

Dynamic OLS

Since the variables in the model come from a system with possible endogenous relationships the DOLS takes account of this by using a two-sided filter which enables to treat all the explanatory variables as weakly exogenous. The following equation is then estimated by OLS:

$$y_t = \boldsymbol{\beta} X_t + \sum_{j=-k_1}^{k_2} \boldsymbol{\gamma}_j \Delta X_{t-j} + \varepsilon_t \tag{6}$$

where y_t is the dependent variable, X_t is a vector of explanatory variables, k_1 and k_2 denote the number of leads and lags, respectively. The length order of leads and lags is determined on the basis of some information criteria for model selection. Presence of cointegration is assessed by testing stationarity of the residuals ε_t. For the purpose of our estimation we set k_1 to one and equal to k_2. This choice is determined by the small sample of observations available to us.

ARDL method

The error correction form of the ARDL model is given by an equation where the dependent variable in first differences is regressed on the lagged values of the dependent and independent variables in levels and first differences.

$$\Delta y_t = \phi y_{t-1} + \beta X_{t-1} + \sum_{j=1}^{p} \delta_j \Delta y_{t-j} + \sum_{j=0}^{l} \gamma_{i,j} \Delta X_{t-j} + \varepsilon_t \tag{7}$$

where y_t is the endogenous variable, X_t is a vector of explanatory and deterministic variables. The disturbance term ε_t is assumed to be independently distributed and independent of the regressors, i.e. $E(\varepsilon_t \mid X_t) = 0$. Further, the underlying $ARDL(p,l)$ model is assumed to be stable, which ensures that $\phi < 0$, and thus there exists a long-run relationship between y_t and X_t defined as:

$$y_t = -\left(\boldsymbol{\beta}' / \phi\right) X_t + \eta_t \tag{8}$$

where η_t is a stationary process. The coefficient standard errors are then obtained using the familiar *delta method*.

Johansen method

The aforementioned single-equation approaches do not enable to test for the presence of more than one co-integrating vector. Therefore, the Johansen co-integration technique is used to determine the number of co-integrating vectors in a vector autoregression (VAR) framework. The max and trace statistics propose by Johansen (see e.g. Johansen, 1995) are used in this respect. The familiar VAR representation is:

$$y_t = \sum_{i=1}^{l+1} A_i y_{t-i} + \psi D_t + v_t \tag{9}$$

which may be reparameterized into the VECM representation as:

$$\Delta y_t = \sum_{i=1}^{l} \Gamma_i \Delta y_{t-i} + \Pi y_{t-1} + \psi D_t + v_t \tag{10}$$

where y_t is a vector of endogenous variables within the system, D_t contains deterministic components and exogenous variables and v_t is assumed to have a mean of zero, be homoscedastic and serially uncorrelated. The order of the VAR is assumed finite to exclude moving average components, and the parameters A_i, U_i, ψ, and Σ (the covariance matrix of v_t) are assumed constant. Π is interpreted as the matrix of long-run responses. If the data co-integrate Π must be of reduced rank, $r < n$, where n is the number of variables in y_t. Π may be factored as $\Pi = \alpha\beta'$ (see Johansen, 1995) where β and α are n x r matrices which give the co-integrating vectors (empirical long-run relationships) and associated adjustment matrix, respectively.

Due to the small sample available to us we consider the maximum of two lags in the lag-length selection process. It appears that both the Hannan-Quin and Bayesian Information criteria suggest that this maximum of two lags is employed. Both criteria are weakly consistent in a case when the lag-length determination is carried out for non-stationary variables. We thus use VAR(2) for the Johansen procedure and maximum of two lags for the ARDL method.

The Trace and Maximum-eigenvalue statistics for the VAR(2) system of the considered variables are reported in table 2:

******* Table 2 Here *******

The Trace statistic indicates presence of two co-integrating vectors at the 1 percent significance level. On the other hand, the Maximum-Eigenvalue statistic indicates presence of only one co-integrating vector within the system. We continue with the more conservative choice of one co-integrating vector that is easily identified in our case by normalizing on the real exchange rate.

6 Estimation Results

The estimates of the model in equation (5) using all three outlined estimation methods are reported in table 3. We apply the general-to-specific approach to arrive at the parsimonious versions of estimates provided in table 3.

******* Table 3 Here *******

All three model estimates satisfy the common diagnostic tests given the results reported in last three rows of table 3. According to the estimates from all three methods employed an increase in the productivity differential between the Czech Republic and Germany results in an appreciation of the real exchange rate of the Czech koruna. An improvement in the terms of trade makes the Czech currency appreciate with respect to the euro (mark) in real terms. Significance of this effect is supported by the DOLS and ARDL estimates. An increase in net foreign assets causes real depreciation of the Czech koruna. This rather contradictory result is only significant when the DOLS estimation method is applied and can be brought about by the interaction between net foreign assets and foreign direct investment in this case. The increasing degree of openness of the Czech economy appears to induce real appreciation of the Czech koruna. This result is however only significant in the case of DOLS. Similarly, the increasing government consumption as a proportion of GDP results in koruna's appreciation with respect to the euro (mark). Such observation can be made only when the DOLS method is applied.

The coefficient estimates attached to the real interest rate differential are significantly positive. This contradicts with expected signs on the interest rate differential based on UIP as shown in the BEER-model derivation. Such result suggests that the positive interest differential with respect to Germany forecasts future appreciation of Czech koruna. The ARDL and JOH estimates suggest that the domestic currency depreciate in real terms against the euro (mark) at a rate equal to about 3 percent of the corresponding interest rate differential. The effect of the foreign direct investment on the real exchange rate is significant and consistent across all three methods with slight variability in the estimates' magnitudes. It appears that an increase in the net FDI inflow to the Czech Republic results in a real appreciation of the koruna.

Even though all three estimation methods employed produce plausible results that satisfy the common diagnostic tests one may want to rely on those that utilize more information than the others. This is especially appropriate in the case like ours when the sample size is very small and the degree of parsimony of the general model specifications for each estimation method differs substantially. In our case, the ARDL estimates are favored on such a premise. However, it is hard to judge the estimates of some unobserved (latent) variables just from the econometric point of view. It might be preferable to look at the economic rationale of the acquired estimates of the BEER. We do so in the next section within the discussion of the resulting misalignments of the real exchange rate of the Czech koruna.

7 Discussion of the Misalignments

When employing the behavioural approach it is possible to distinguish between two types of misalignments, i.e. deviations of the actual exchange rate from an estimate of its equilibrium values. The first deviation of interest is the current (*speculative*) misalignment, which is determined by the deviation of the *actual* real exchange rate from the estimated equilibrium real exchange rate given by the conditioning set of *actual* fundamentals. This misalignment measures the actual deviations from the equilibrium exchange rate of the Czech koruna in the short-run. We present the short-run misalignments in figure 1 below for the three estimation methods. In addition, we calculate a weighted average of the three misalignments where each misalignment is scaled according to its relative variance. Plot of the latter quantity is also presented in figure 1.

******* Figure 1 Here *******

The estimates of the BEER imply that the Czech koruna was on average undervalued over the period 1994 to 2004 by about 7 percent with respect to the short-run BEER. The highest average undervaluation is implied by the JOH estimates of about 12 percent. In general, the periods of major undervaluations appear to happened at the end of the year 1996, at the beginning of 1998, and during 2001. The periods of major overvaluation then appeared around the beginning of the year 1997 and 1999, and at the beginning of 2003.

The second deviation of interest is the total (*cyclical* plus *speculative*) misalignment determined by the deviation of the *actual* real exchange rate from the estimated equilibrium real exchange rate based on the *sustainable* values of the fundamentals. The sustainable values of the estimated equilibrium exchange rate are obtained by applying some cyclical filter to the latter estimates; one example being the Hodrick-Prescott (HP) filter. We apply the HP filter to the quarterly estimates of the BEER according to the three estimation methods. The resulting misalignment then corresponds to the equilibrium exchange rate of the Czech koruna in the medium run. The medium-run misalignments of the Czech koruna are plotted in figure 2 (where we have imposed zero average undervaluation). The weighted average of the misalignments is presented as well using again the relative variances as the scaling factors.

******* Figure 2 Here *******

The estimated PEER misalignments suggest that the major undervaluation periods took place during 1995 and from 1999 to the end of the first half of 2000. On the other hand, the major overvaluation emerged about the beginning of 1997, in mid 1998 and during 2002.

Next, we would like to test the economic rationale and information content of the implied misalignments by looking at their impacts on the dynamics of the real exchange rate. If the misalignment is well estimated it should contain considerable information about the future exchange rate dynamics. This intuition is captured by the following error-correction model:

$$\triangle q_t = \alpha\left(q_{t-1} - q_t^{BEER}\right) + \sum_{j=1}^{p_1} \delta_j \triangle q_{t-j} + \sum_{i=1}^{p_2} \gamma_i \triangle X_{t-i} + \nu_t \tag{11}$$

where q_t^{BEER} are the estimates of the BEER using DOLS, ARDL and JOH, respectively. Except for the error-correction tem $q_{t-1} - q_t^{BEER}$, we condition on the same information when estimating the error-correction models with the different estimates of q_t^{BEER} by OLS. Thus the model in which α is most significant and delivers the highest R-squared or adjusted R-squared is likely to contain the most accurate estimation of the BEER of the Czech koruna. We report the estimates of the α coefficients and the associated adjusted R-squares from the reduced error-correction models (the $\triangle X_{t-i}$ are not considered when equation (11) is estimated) in table 4:

******* Table 4 Here *******

Since all the estimates of the α coefficients are significant and negative all the BEER estimates follow correct economic rationale. Further, according to the adjusted R-squares and the relative significance of the α coefficients the BEER estimated by the ARDL method conveys the most accurate information about the true real equilibrium exchange rate of the Czech koruna. The ARDL method uses the most parsimonious general model when it comes to estimation, produces estimates that satisfy all the applied diagnostic tests and provides most informative estimates of the equilibrium exchange rate. As a result one may want to consider the fundamental determinants of the equilibrium ER proposed by this method in discussions about the prospective central parity of the Czech koruna for the ERMII.

8 Conclusion

The primary objective of this paper was to analyse the misalignments of the real exchange rate of the Czech koruna using the behavioural equilibrium exchange rate model. We derive the BEER model of the Czech koruna along the lines of the BEER approach due to MacDonald (1997, 2000). This model is then used to analyse the short-term and medium-term misalignments of the Czech koruna. The initial model specification includes the productivity differential, foreign direct investment, the terms of trade, openness, net foreign assets, government consumption, and the real interest rate differential as potential fundamental determinants of the real exchange rate of the Czech koruna with respect to the euro (the Deutsche mark). We use several estimation methods suitable for non-stationary time series to estimate the derived BEER model and check on the robustness of the acquired estimates. We find that the Czech koruna was on average undervalued over the period 1994 to 2004 by about 7 percent with respect to its BEER estimate. According to our estimates, the periods of major undervaluations appeared at the end of the year 1996, at the beginning of 1998, and during 2001. The periods of major overvaluation then appeared about the beginning of the year 1997 and 1999, and at the beginning of 2003. The ARDL estimates of the equilibrium exchange rate seem to be the most preferable in our case and one may want to consider the significant determinants suggested by this estimation method in deliberations on the prospective central parity of the Czech koruna for the ERMII. These determinants are the productivity differential, the real interest rate differential, the terms of trade and the net foreign direct investment.

References

CLARK, P. - MACDONALD, R. (2000): Filtering the BEER - A Permanent and Transitory Decomposition, IMF Working Paper, 144. Washington D.C.

CLARK, P. – MACDONALD, R. (1998). Exchange Rates and Economic Fundamentals: A Methodological Comparison of BEERs and FEERs. IMF Working Paper, 98/67.

ECB (2003). Policy position of the Governing Council of the ECB on Exchange Rate Issues Relating to the Acceding Countries. European Central Bank, Frankfurt am Main (18th December 2003).

ÉGERT, B. - LOMMATZSCH, K. (2003): Equilibrium Real Exchange Rates in CEE Acceding Countries: How Large Is Our Confidence (Interval)? *Focus on Transition*, 2, 107-137.

ÉGERT, B. (2003). Assessing Equilibrium Exchange Rates in CEE Acceding Countries: Can We Have DEER with BEER without FEER? A Critical Survey of the Literature. Oesterreichische Nationalbank, *Focus on Transition*, 2, pp. 38-106.

ELLIOT, G. - ROTHENBERG, T. - STOCK, J. H. (1996). Efficient Tests for an Autoregressive Unit Root. *Econometrica*, vol. 34, p. 813-836.

FRAIT, J. - KOMÁREK, L. (1999): Long-Term Determinants of the Equilibrium Real Exchange Rate of the Czech Koruna. Czech National Bank Working Paper, 9.

FRAIT, J. – KOMÁREK, L. (2001). Real Exchange Rate Trends in Transitional Countries. Warwick Economics Research Papers, 596. University of Warwick.

GONZALO, J. – GRANGER, C. W. (1995). Estimation of Common Long-Memory Components in Cointegrated Systems. *Journal of Business Economics and Statistics*, vol. 13, 27.35.

ISARD, P. - FARUQEE, H. (1998). Exchange Rate Assessment: Extensions of the Macroeconomic Balance Approach. IMF Occasional Paper, 167, Washington DC.

JOHANSEN, S. (1995). *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models*. Oxford, Oxford University Press.

KAMINSKI, G. – LIZONDO, S. – REINHART, C. (1997). Leading Indicators of Currency Crises. IMF Working Paper, 97/79.

MACDONALD, R. (2000). Concept to Calculate Equilibrium Exchange Rate: An Overview. Deutsche Bundesbank Discussion Paper, 3/00. Economic Research Group of the Deutsche Bundesbank.

MACDONALD, R. (1997). What Determines Real Exchange Rate? The Long and Short of It. IMF Working Paper, 97/21.

PESARAN, M. H. - SHIN, Y. (1999). An Autoregressive Distributed Lag Approach to Cointegration Analysis, in S. Strom (ed.), *Econometrics and Economic Theory in the 20th Century: The Ragnar Frisch Centennial Symposium*, Cambridge University Press.

PESARAN, M.H. - SHIN, Y. (1995). An Autoregressive Distributed Lag Modelling Approach to Cointegration Analysis. DAE Working Paper, 9514. Department of Applied Economics, University of Cambridge.

RAZIN, O. – COLLINS, S. (1997): Real Exchange Rate Misalignments and Growth. In: Razin, A. – Sadka, E. (eds.): *International Economic Integration: Public Economics Perspectives*. Cambridge, Cambridge University Press, 1997.

SAIKKONEN, P. (1991). Asymptotically Efficient Estimation of Cointegration Regressions. *Econometric Theory*, 7, 1–21.

STEIN, J. – ALLEN, P. (1995). *Fundamental Determinants of Exchange Rates*. Oxford, Clarendon Press.

STEIN, J. (1994). The Natural Real Exchange Rate of the US-dollar and Determinants of Capital Flows. In: J. Williamson: *Estimating Equilibrium Exchange Rates*. Washington, D. C., 133-176.

STOCK, J. H. - WATSON, M. W. (1993). A Simple Estimator of Cointegrating Vectors in Higher Order Integrated Systems. *Econometrica*, 61, 1035-1056.

WILLIAMSON, J. (1994). Estimating equilibrium exchange rates. Institute for International Economics, Washington, D.C.

Appendix

******* Table A1 Here *******

References

ALBEROLA, E. (2003): Real Convergence, External Disequilibria and Equilibrium Exchange Rates in EU Acceding Countries. Bank of Spain.

ALONSO-GAMO, P. – S. FABRIZIO, S. – KRAMARENKO, V. – WANG, Q. (2002): Lithuania: History and Future of the Currency Board Arrangement. IMF Working Paper, 127.

AVALLONE, N. – LAHRÈCHE-RÉVIL, A. (1999): Le taux de change réel d'équilibre dans les pays en transition : le cas de la Hongrie, TEAM, Université Paris 1, Cahiers blancs 1999/91.

BEGG, D. – HALPERN, L. – WYPLOSZ, CH. (1999): Monetary and Exchange Rate Policies, EMU and Central and Eastern Europe. *Forum Report on the Economic Policy Initiative,* No. 5. London: CEPR and New York, Prague: EastWest Institute.

BEGUNA, A. (2002): Competitiveness and the Equilibrium Exchange Rate in Latvia. University of Latvia and EuroFaculty. EuroFaculty Working Paper in Economics, No. 16 (August).

BITANS, M. – TILLERS, I. (2003): Estimates of Equilibrium Exchange Rate in Latvia. Latvijas Banka. Analysis of the Real Exchange Rate in Latvia: 1994-2001. Latvijas Banka. Mimeo.

BITANS, M. (2002): Real Exchange Rate in Latvia: 1994-2001. Latvijas Banka Working Paper.

BURGESS, R. – FABRIZIO, S. – XIAO. Y. (2003): Competitiveness in the Baltics in the Run-Up to EU Accession. IMF Country Report 114.

CORICELLI, F. – JAZBEC, B. (2001): Real Exchange Rate Dynamics in Transition Economies, Centre for Economic Policy, Research, Discussion Papers Series, No. 2869, July

COUDERT, V. (1999): Comment Définir un Taux de Change D´équilibre Pour Les Pays Émergents*? Economie Internationale,*. 77. 1er trimestre. 45-65.

CSAJBÓK, A. (2003): The Equilibrium Real Exchange Rate in Hungary: Results from Alternative Approaches. 2nd workshop on Macroeconomic Policy Research. Magyar Nemzeti Bank, October.

DARVAS, Z. (2001): Exchange Rate Pass-Through and Real Exchange Rate in EU Candidate Countries. Economic Research Centre of the Deutsche Bundesbank Discussion Paper, 10.

DE BROECK, M. – SLØK, T. (2001): Interpreting Real Exchange Rate Movements in Transition Countries. IMF Working Paper*,* No. 56/01.

DOBRINSKY, R. (2003): Convergence in Per Capita Income Levels, Productivity Dynamics and Real Exchange Rates in the EU Acceding Countries. *Empirica*, 30(3). 305-334.

ÉGERT, B. – LAHRÈCHE-RÉVIL, A. (2003): Estimating the Equilibrium Exchange Rate of Central and Eastern European Countries: The Challenge of euro adoption. *Weltwirtschaftliches Archiv,* 139(4). 683-708.

ÉGERT, B. – LOMMATZSCH, K. (2003): Equilibrium Real Exchange Rates in CEE Acceding countries: How Large Is Our Confidence (Interval)? *Focus on Transition,* No. 2. 107-137.

FILIPOZZI, F. (2000): Equilibrium Exchange rate of the Estonian kroon, its Dynamics and Its Impacts of Deviations. Bank of Estonia Working Paper, No. 2.

FISCHER, C. (2002): Real Currency Appreciation in Accession Countries: Balassa-Samuelson and Investment Demand. BOFIT Discussion Paper, No. 8. Institute for Economies in Transition.

FRAIT, J. – KOMÁREK, L. (1999): Long –term determinants of the Equilibrium Real Exchange Rate of Czech Koruna. Czech National Bank Working Paper, No. 9. [in Czech].

FRAIT, J. – KOMÁREK, L. (2001): Real Exchange Rate Trends in Transitional Countries, *Warwick Economics Research Papers*, No 596. Department of Economics, University of Warwick.

HALPERN, L. – WYPLOSZ, CH. (1997): Equilibrium Real Exchange Rates in Transition Economies. *IMF Staff Papers*, No. 4 (December).

HINNOSAR, M. – R. JUKS, H. – KAADU – L. UUSKÜLA. (2003). Estimating the Equilibrium Exchange Rate of the Estonian Kroon. Bank of Estonia. mimeo.

INTERNATIONAL MONETARY FUND (1998): Republic of Slovakia: Recent Economic Developments. *IMF Staff Country Report*, No. 98/60, 41-47. Washington D.C.

KAZAKS, M. (2000): Real exchange rate appreciation and loss of competitiveness: the Case of Latvia. The Second Seminar of Managing Economic Transition in Eastern Europe. May 24. University College London. School of Slavonic and East European Studies.

KIM, B.Y. – KORHONEN, I. (2002): Equilibrium Exchange Rates in Transition Countries: Evidence from Dynamic Heterogeneous Panel Models. BOFIT Discussion Papers, No. 15.

KRAJNYÁK, K. – ZETTELMEYER, J. (1998): Competitiveness in Transition Economies: What Scope for Real Appreciation? *IMF Staff Papers*, No. 45.

LOMMATZSCH, K. – TOBER, S. (2002): What is Behind the Real Appreciation of the Accession Countries' Currencies? An investigation of the PPI-based Real Exchange Rate. Exchange rate Strategies During the EU Enlargement. Budapest. 27-30 November.

MACDONALD, R. – WÓJCIK, C. (2002): Catchting Up: The Role of Demand and Supply Side Effects on the Real Exchange Rate of Accession Countries. Oesterreichische Nationalbank. *Focus on Transition* , No. 2/2002.

MAURIN, L. (2001): Fundamental Determinants of RER for Transition Countries. In: Stierle, M. H. and T. Birringer (eds.). *Economics of Transition: Theory, Experiences and EU-Elargement*. Berlin.

RAHN, J. (2003): Bilateral Equilibrium Exchange Rates of the EU Accession Countries Against the Euro. BOFIT Discussion Papers, No. 11.

RANDVEER, M. – M. RELL (2002): The Relationship Between Competitiveness and Real Exchange Rate in Estonia. Eesti Pank Research Paper.

RAWDANOWICZ, W. (2003): Poland's Accession to EMU: Choosing the Exchange Rate Parity. CASE Studies & Analyses, 247.

RUBASZEK, M. (2003): A Model of Balance of Payments Equilibrium Exchange Rate: Application to the Zloty. Narodowy Bank Polski. Mimeo.

VETLOV, I. (2002): Analysis of the Real Exchange Rate and Competitiveness in Lithuania. Eesti Pank Research Paper.

******* Figure A1 Here *******

Tables

Table 1: Unit Root Tests

Variable		Unit root test DF-GLS
rer	*Levels*	-2.5991 [c,t]
	1st diff	-4.7170 [c]***
prod	*Levels*	-2.0161 [c,t]
	1st diff	-5.5330 [c]***
nfa	*Levels*	-1.6385 [c,t]
	1st diff s	-3.8980 [c]***
open	*Levels*	-2.4506 [c,t]
	1st diff	-5.3263 [c]***
rird	*Levels*	-2.7543 [c]***
	1st diff	-4.6169 ***
gs	*Levels*	-1.0459 [c]
	1st diff	-5.7741 ***
tot	*Levels*	-2.7085 [c]***
	1st diff	-3.2450 ***

c or t in the square brackets represent inclusion of a constant or a time trend in the regression underlying the test.

Table 2 Cointegration Rank Test

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	1 % Critical Values	Max-Eigen. Statistic	1 % Critical Values
$r = 0$	0.921581	211.2254*	133.57	96.73611*	51.57
$r \leq 1$	0.644727	114.4893*	103.18	39.32500	45.10
$r \leq 2$	0.513163	75.16430	76.07	27.35339	38.77
$r \leq 3$	0.484161	47.81091	54.46	25.15453	32.24
$r \leq 4$	0.278751	22.65638	35.65	12.41727	25.52
$r \leq 5$	0.176734	10.23912	20.04	7.390105	18.63
$r \leq 6$	0.072232	2.849013	6.65	2.849013	6.65

* denotes rejection of the hypothesis at the 1% level. All the variables considered are assumed to be potentially endogenous except for the terms of trade.

Table 3 Estimations of the BEER model of the Czech koruna

Variable/Method	DOLS(1,1)	ARDL(1,0,0,2,1)	JOH(2)
prod	-4.4375 (1.9484)**	-3.7471 (0.5612)***	-2.1708 (0.7180)***
tot	-4.5947 (1.0861)***	-1.1531 (0.5188)**	-----
nfa	2.1548 (0.7250)**	-----	-----
open	-4.1612 (1.0165)***	-----	-----
gs	-3.7155 (0.8643)***	-----	-----
rird	-----	0.0361 (0.0155)**	0.0256 (0.0107)**
fdi	-0.5991 (0.1685)***	-0.0980 (0.0274)***	-0.1692 (0.0368)***
constant	75.557 (19.5446)***	27.5557 (3.8185)***	15.276 (3.2295)***
Serial Correlation AR(4)	1.2965 [0.3487]	2.0673 [0.1140]	0.16288 [0.9204]
Normality	0.9089 [0.6348]	0.60211 [0.7400]	4.4839 [0.1063]
Heteroscedasticity	0.2896 [0.9641]	0.56566 [0.4570]	0.79672 [0.6710]

*,**,*** - stand for significance at 10 %, 5 % and 1 % level, respectively. Standard errors are in parentheses. The probability level of the diagnostic tests is in square brackets.

Table 4 Estimates of the Reduced Error-Correction Models

Coefficient/Model	q_t^{BEER} by DOLS	q_t^{BEER} by ARDL	q_t^{BEER} by JOH
α	-0.0825 (0.0316)**	-0.1733 (0.0391)***	-0.1033 (0.0275)***
Adj. R-squared	0.0748	0.2841	0.2075

*, **, *** - stand for significance at 10 %, 5 % and 1 % level, respectively. Standard errors are in parentheses.

Table A1 An overview of RER determinants based on other empirical studies

STUDY BY	PROD	GOV	OPEN	NFA	RIRD	TOT	INV	FD	PC	RP	FDI	variab.
Alberola (2003)	–			–/+								2
Alonso-Gamo et al. (2002)	–			+								2
Avallone and Lahrèche-Révil (1999)	–	–	+			–			–			5
Begg et al. (1999)	–	–	–									3
Beguna (2002)		–	–			–					–	4
Bitans (2002)	–	+	+									3
Bitans and Tillers (2003)	–			–		+						3
Burgess et al. (2003)	–			+								3
Coricelli and Jazbec (2001)	–	–							–			3
Coudert (1999)	–							+				2
Csajbók (2003)	–	–	–	–	–	–						6
Darvas (2001)	–			–	–/+							3
De Broeck and Sløk (2001)	–		+									2
Dobrinsky (2003)	–	–										2
Égert and Lahrèche-Révil (2003)	–											1
Égert and Lommatzsch (2003)	–		+		–			–/+		–		5
Filipozzi (2000)	–						–					2
Fischer (2002)	–	–			–/+	+						4
Frait and Komárek (1999, 2001)	–				+	–			(–)		–	4
Halpern and Wyplosz (1997)	–	–										2
Hinnosar et al. (2003)	–			–		–						3
IMF (1998)	–	+	–				+					4
Kazaks (2000)	–		+									2
Kim and Korhonen (2002)	–	–	+				–					4
Krajnyák and Zettelmeyer (1998)	–											1
Lommatzsch and Tober (2002b)	–			+	–							3
MacDonald and Wójcik (2002)	–			–/+	–					–		4
Maurin (2001)	–	–			–			+				4
Rahn (2003)	–			–								3
Randveer and Rell (2002)	–					–						2
Rawdanowicz (2003)	–				–	–						3
Rubaszek (2003)				–	–							2
Vetlov (2002)	–		+		+							3
Number of '–'	31	10	4	8	9	7	2	1	2	2	2	X
Number of '+'	0	2	7	5	3	2	1	3	0	0	0	X
Total number of studies	31	12	11	11	10	9	3	3	2	2	2	X

Source: Based on Égert (2003) and authors update.

Notes: –, + increase in the variable leads to an appreciation or depreciation of the real exchange rate, respectively. PROD = productivity proxy; GOV = share of government consumption in GDP; OPEN = exports + imports over GDP; NFA = net foreign assets; RIRD = real interest differential; TOT = terms of trade = export prices / import prices; INV = share of investment in GDP; FD = foreign debt to GDP; PC = share of private consumption in GDP; RP = regulated prices (or the differential towards the benchmark economy), FDI = foreign direct investment over GDP, S = national savings over GDP.

Figures

Figure 1 Short-Run BEER Misalignment of the Czech Koruna

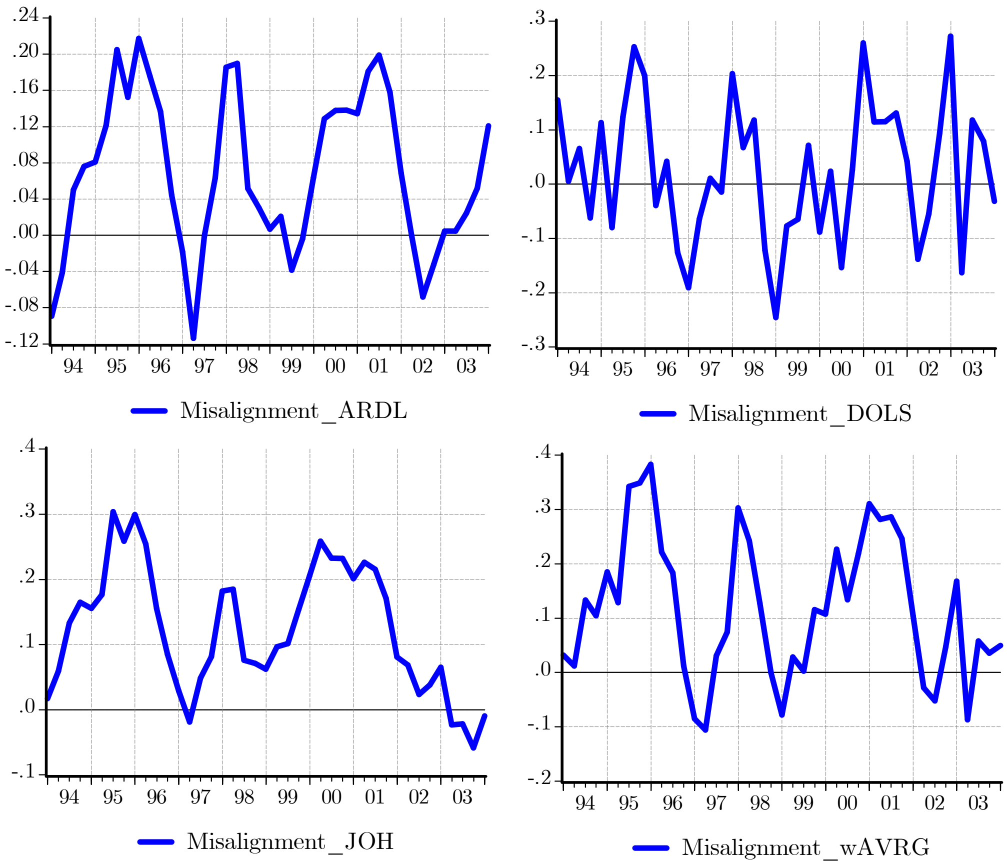


Figure 2 Medium-Run BEER Misalignment of the Czech Koruna

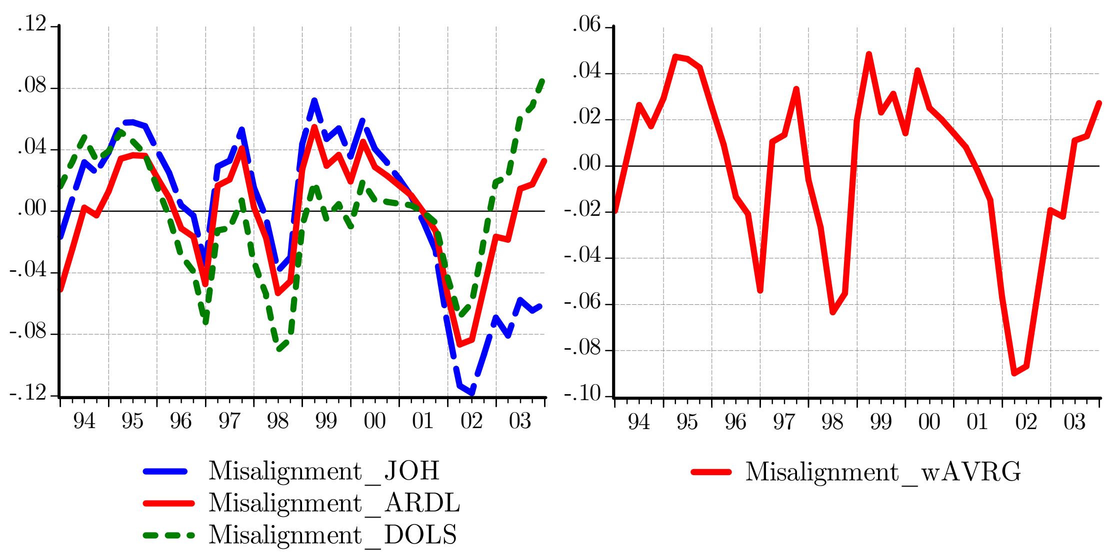
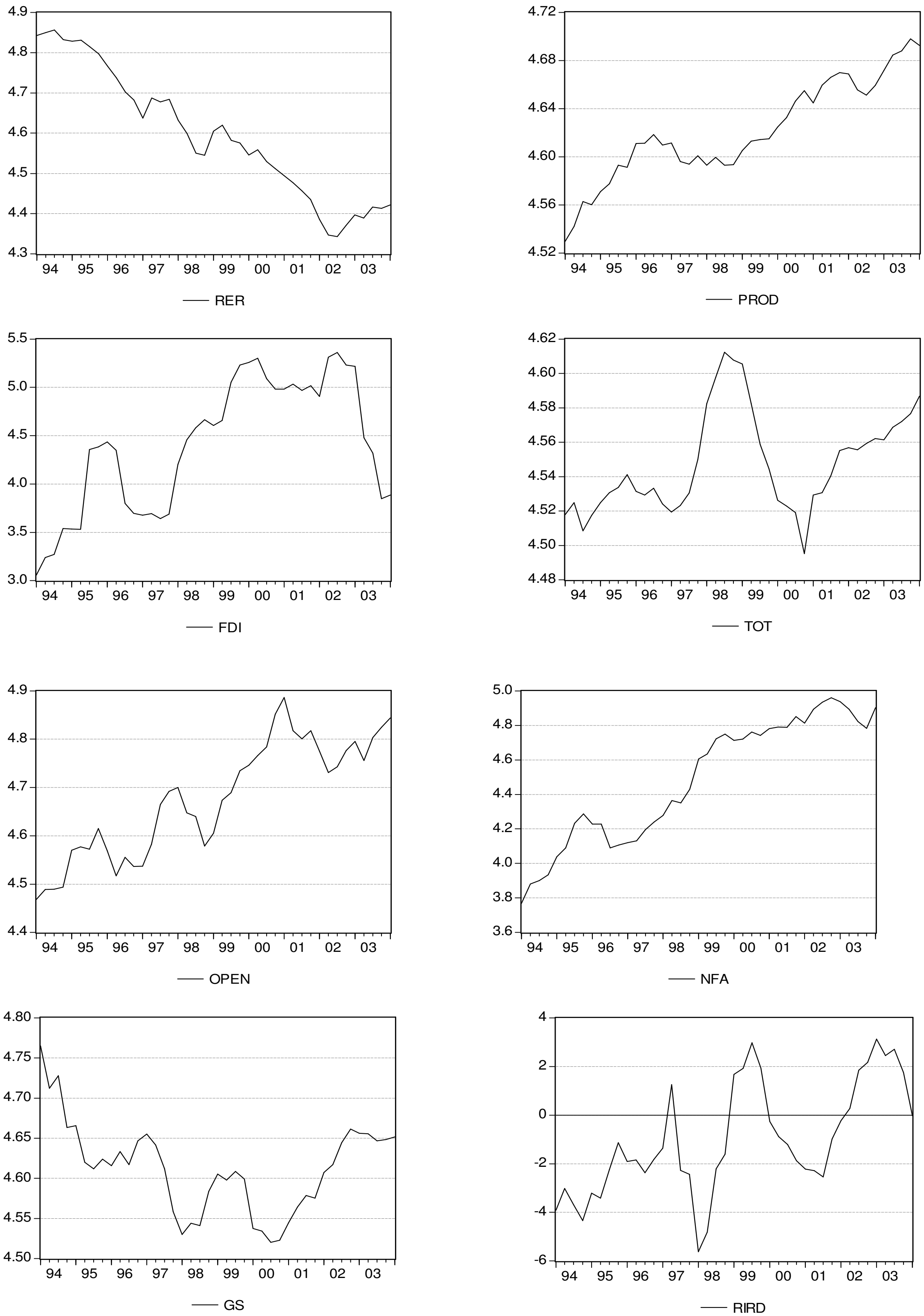


Figure A1 Development of the Main Fundamental Determinants



Note: variables presented in logarithms, except RIRD.